RESEARCH DEPARTMENT

Psychoacoustic criteria for background noise and sound insulation in broadcasting studios

RESEARCH REPORT No. PH-5

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THE BRITISH BROADCASTING CORPORATION
ENGINEERING DIVISION

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PSYCHOACOUSTIC CRITERIA FOR BACKGROUND NOISE AND SOUND INSULATION IN BROADCASTING STUDIOS

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SUMMARY

This report summarises the criteria at present used to guide the design of studios with respect to background noise and sound insulation. Many of these criteria have been difficult to determine by definitive experiments and have therefore been evolved by experience and indirect methods which are described in this report, together with specifications for measurement. The final sections give recommendations for sound insulation so that the required low noise levels can be achieved.

1. INTRODUCTION

At a very early stage in the planning of broadcasting studios it is necessary to take into consideration the sound insulation of the studios against external noise and from noise sources, such as ventilation systems, which form part of the studio. The cost of rectifying inadequate designs after the studio has been built is extremely high, but it would be equally uneconomic to introduce unnecessarily large factors of safety. For this reason, the specification of maximum permissible background noise levels, the sound insulation required to achieve such levels, and of maximum noise radiation from studio equipment has been continually under review for many years.

Recently contractors who have been working to these specifications have, in several instances, acquired equipment to carry out their own measurements instead of relying upon BBC measurements on the completed installations. This has forced a revision of some specifications since our measurements, for good reasons, have not always followed British Standards Institution recommendations (as, for instance, in the use of peak-reading instead of r.m.s. meters).

This report, therefore, is intended to present a coherent statement of all design criteria in the field of studio design, in a form which will be valid both within and outside the BBC.

2. BACKGROUND NOISE

2.1. Introduction

The permissible studio noise level forming a background to the programme depends upon many factors, such as the acceptable signal-to-noise ratio, the distance of the microphone from the sound source, the loudness of the source and the directivity of the microphone.

The measurement and specification of noise levels present difficulties, first because the reading of any indicating or recording instrument depends on the waveform and the uniformity of the noise signal, and secondly because only a specification giving acceptable levels in every octave or 1/3rd octave-band is found to be satisfactory. It is proposed therefore in this section first to examine the accuracy of measurement and then to describe methods which have been used to determine the limiting tolerable levels. Finally, specifications will be given for various types of noise.

2.2. Basis of Measurement and Summation

2.2.1. Measurement

It is customary to refer all sound pressure levels, expressed in decibels, to a standard level of $2 \times 10^{-5}\,\mathrm{N/m^2}$ which is comparable with the threshold of hearing at 1000 Hz. A noise-measuring system normally consists of a calibrated microphone having an omnidirectional characteristic, a calibrated amplifier and a detector which may take the form of a meter or a high-speed level recorder, preceded in both cases by a rectification process, the characteristics of which determine the indicated level. For instance, the meter may indicate the peak, the mean or the root-mean-square value of the waveform. All meters will agree on a pure sinusoidal waveform, so long as it is remembered that the r.m.s. value is $1/\sqrt{2}$ of the peak value (3 dB lower) and the mean value of the rectified waveform is 3·9 dB below the peak value. For general waveforms the peak is not well defined. The precise reading of a peak rectifier will depend on charge and discharge time constants.

B.S. 3489:1962 makes the use of an r.m.s. meter obligatory for noise measurement and therefore specifications must be written in terms of this type of measurement. Most of the past work by Research Department has however been carried out with peak-reading instruments because of the subjective importance of impulsive noises which may have too low a repetition rate to give a reading on an r.m.s. meter. In this section, therefore, an attempt will be made to estimate the corrections which should be applied to reconcile the two systems of measurement.

The following table (Table 1) shows the indications given by five different systems using impulsive noise of two kinds both as broad-band noise and also when separated into 1/3-octave or octave-bands. All levels are referred to the reading on an r.m.s. instrument, the Brüel and Kjaer spectrometer switched to r.m.s. indication, and all systems gave equal results on a pure sinusoid.*

* Care should be exercised, however, in using the meter indications of the B and K spectrometer since this instrument gives true relative readings for peak, mean and r.m.s., whereas all single-purpose instruments are calibrated by inserting a known calibrating voltage and therefore should give equal readings for the same sinusoid whether peak or mean indication is used.

It is clear from these figures that great care must be taken when quoting measurements or writing specifications to be explicit on the method of measurement and on the reasons for using that method.

In the field of communications, there seems to be general agreement to the use of peak measurement, probably with the object of rating correctly intermittent disturbances such as teleprinter noise on lines or footsteps in studios. Thus the Post Office and the BBC both use peak programme meters with rise times of a few milliseconds and long decay times.

King(1) reports that the subjective loudness of sounds of equal r.m.s. value increases with the number of components in the noise as does the peak to r.m.s. ratio. This result suggests that r.m.s. readings give low results on complex waveforms and that peak readings may be more nearly correct. On the other hand Maurice et al(2), after a very thorough series of tests, found that r.m.s. was a better indication of subjective loudness of noise and of annoyance in the presence of programme. This conclusion is at variance with our own findings in several series of experiments which appeared to

TABLE I

Comparison Between Measurements with Various Indicating Instruments

Instrument	Random Noise			Falling-Ball Calibrator			Ventilation Noise		
	Whole	Octave	1/3 Oct	Whole	Octave	1/3 Oct	Whole	Octave	1/3 Oct
Valve Voltmeter *	−0·6	−1·0	−0·5	−0·4	0	0		−0·5	0
Test Programme Meter **	+4·2	+5·0	+5·0	+7·6	+5·0 to +10·0	+4·0 to +11·0	+5·0	+5·0	+6·0
B and K Recorder Type 2304 ***	−2·0 to +2·5	+4·0 to +3·0	+3·0 to +4·0	+4·0	+5·0	+4·5	+3·0	+5·0	+6·0
B and K Spectrometer (Peak) Type 2112	+3·2	+7·0	+7·0	+4·1	rising +5·0 to +11·0	+5·0 to +10·0	+7·0 to +10·0	+7·0	+8·0
B and K Recorder (Peak) Type 2305	+8·0	+4·0 to +8·0	+4·0 to +8·0	+7·0	+5·0 to +9·5	+2·0 to +11·0	+8·0	+6·0 to +13·0	+3·0 to +8·0

* *Indicating mean of modulus of signal*

** *Peak-reading instrument, 3 ms. rise time, 3 sec. decay*

*** *Peak indicator with variable time constant*

show that peak readings were more indicative of subjective sensations even on continuous waveforms.

Fortunately, the figures of Table 1 show that for such quasi-random noises as ventilation or traffic noise, the peak-to-mean ratio is not very variable and that, within this field of work, either type of measurement is valid, provided that all measurements and specifications follow the same type or are properly corrected.

The only means of deciding on the method of measurement, therefore is by the performance with intermittent sounds such as those mentioned above, and here the peak-reading instrument is undoubtedly the best.

The use of the Peak Programme Meter and the high-speed level recorder in the peak-reading condition will therefore be continued, but for measurements and specifications of background noise where other organisations are involved, r.m.s. values will be quoted in accordance with B.S. 3489:1962. Readings of ventilation noise with a Dawe Sound Level Meter conforming to B.S. 3489:1962 are found to be up to 13 dB lower than those obtained by various peak-reading instruments. It is therefore clear that our earlier specifications, which did not utilise the British Standards Institution methods of measurement, must be suitably adjusted. From Table 1 a correction of 5 dB will be seen to be suitable for the great majority of Research Department results for which either programme meters or Type 2304 B and K Sound Level Recorders have been used.

2.2.2. Methods of Summation

For some purposes it is desirable to express the loudness of a noise as a single figure. It is common practice to use a single figure for line or amplifier noise weighted by the introduction of an aural sensitivity network, and a similar principle is used in sound-level meters.

A sound-level meter consists of a microphone, an amplifier and an indicating meter. Before the indicating circuit there may be one of several frequency-weighting networks intended to represent ear-like characteristics at various pressure levels. The only weighting network of importance is the 'A' network defined in British Standard 3489:1962, which follows the ear sensitivity at low pressure levels and which is also found to give the best correlation with the subjective rating of traffic noise. The indication is nominally r.m.s. and the readings are stated in "decibels (A network)" or "dB(A)"

Alternatively, a summation can be obtained from the sound pressure levels in octave or 1/3rd octave bands. The method in either case is to convert the band pressure levels to the sone* scale, an arithmetic scale of loudness which perhaps by chance is additive, and to combine these by addition and conversion to phons. Two methods are described in a British Standard shortly to be published. A method proposed by Stevens(3) uses octave bands while that of Zwicker(4) is more complicated, using one-third octave bands except at very low frequencies and taking into account the masking effects in each band by sound of lower frequency.

Each of these two methods gives an answer in phons which is substantially equal to that obtained from direct subjective comparison with 1 kHz tone. The sound level meter, however, gives a much lower indication, readings in dB(A) for broad-band noise being from 10 dB to 18 dB lower than computed phons, depending on the intensity of the noise. On certain types of noise, such as pure tones, however, dB(A) may be a good approximation to phons.

The dB(A) reading should be used only for rough comparisons of sounds of similar type, e.g. for assessing the level of traffic noise in an office. For all other purposes, octave-band analysis with or without summation is essential.

2.3. Physiological Effects of Loud Sounds

2.3.1. Noise-Induced Hearing Loss

The main part of this report is concerned with the audibility of faint unwanted noise on programmes. It is also necessary to examine the physical effects on the ear of loud sounds, such as those sometimes used for monitoring. It is well-known that very intense sounds such as gunfire can cause temporary or permanent deafness; in broadcasting it is unlikely that major damage of this kind could occur, but somewhat lower sound levels, if experienced for a sufficiently long time, can produce disabling shifts in the hearing threshold.

Age produces a raising of the hearing threshold without any exposure to particularly intense sounds and this makes it difficult after the event to assess hearing damage due to exposure. At a retiring age of 60, the average person has lost hearing acuity to the extent of 10 dB at 1 kHz and 28 dB at 8 kHz compared with the age of 20. Men show slightly larger losses than women.

* If L is the loudness level in phons equivalent to N sones, by definition,

$$\log_{10} N = 0{\cdot}03L - 1{\cdot}2$$

Occupational hearing loss due to exposure to loud sounds with wide spectra generally starts at 4 kHz and spreads to neighbouring frequencies as exposure continues. In some noisy industries, hearing losses as high as 60 dB at this frequency have been recorded after twenty years of continuous exposure. Exposure to a single frequency or narrow band of frequencies produces a maximum threshold shift at a frequency more than half an octave higher.

Two degrees of impairment are recognised, a temporary shift in the auditory threshold, which recovers between successive days' exposure, and permanent damage which remains indefinitely after exposure. It is found that noise experienced for not more than five hours per day and causing less than 12 dB temporary shift at the end of the day is unlikely to cause any permanent impairment of hearing. With this criterion it should be possible to estimate conservatively the probable effects of noise exposure in the course of any type of BBC work.

According to Glorig, Ward and Nixon(5), hearing conservation measures should be initiated when the sound pressure level in any octave band exceeds the levels shown in Table 2 for more than five hours per day.

If the exposure time is reduced to 30 minutes per day, these levels may be increased by about 10 dB.

2.3.2. Sound Levels Experienced in Monitoring Programmes

The available data on listening levels is mostly expressed as an intensity level measured with a BBC peak programme meter without reference to frequency, and presumably refers to an unweighted frequency band from about 30 Hz to 10,000 Hz, or about eight octaves.

Somerville and Brownless(6) found by a careful set of experiments, that members of the public preferred higher levels for symphonic music than for any other type of programme, the average subject preferring peak listening levels of 78 dB above the usual reference level. The preferred level for speech was 71 dB; other types of music fell between these extremes.*

Specialist groups such as musicians, studio managers and engineers preferred levels about 10 dB higher than the general public, their chosen levels for symphonic music ranging from 87 to 90 dB. Exposure to such high levels would be only occasional, probably lasting altogether less than half an hour or so per day. From the criterion of Glorig, Ward and Nixon quoted above and the correction for reduced time, these levels are probably safe. The maximum intensity in an orchestral performance is usually in the region of 500 Hz and at this frequency 98 dB measured by an r.m.s. meter in a single octave band would be considered safe; this should be compared with 90 dB peaks for the whole audio-frequency band found by Somerville and Brownless.

A recent check, using a few subjects in Research Department, showed that the maximum tolerable levels for monitoring amounted to between 100 and 106 dB, which was found by octave band analysis to correspond to between 90 and 101 dB in the 500 Hz centred octave band.

It is therefore possible that some studio managers or their equivalents in other organisations occasionally expose their ears to sound levels, which, if maintained, could cause hearing loss; most of them, however, listen at levels which may be considered harmless. Since the publication of the paper by Somerville and Brownless drew attention to the discrepancy between monitoring levels and home listening levels, there has been a tendency to reduce monitoring levels in order to obtain a balance between high and low frequencies which will be correct at home listening levels.

Partial confirmation of these findings has recently been obtained by some audiometric tests on a group of music studio managers whose thresholds were tested before and after a duty session.

* This investigation took place before the advent of "beat" groups equipped with electric guitars.

TABLE 2

Sound Pressure Levels at Which Hearing Conservation Measures Should be Initiated

Octave mid-frequency Hz	63	125	250	500	1000	2000	4000	8000
Sound Pressure Level (dB relative to 2×10^{-5} N/m^2)	103	96	91	88	85	83	81	79

No signs of temporary threshold shift could be found, nor did their audiograms appear in any way abnormal compared with those of normal subjects of the same age.

It would appear that a far greater risk of permanent damage to the hearing would be encountered by musicians playing in orchestras and bands, particularly those normally sitting near to the louder brass instruments. Manson, Shorter and Nash(7) measured sound pressure levels up to 129 dB rel. to 2×10^{-5} N/m^2 on single notes measured at a distance of 0·75 m from the bell of a trumpet and up to 138 dB at a distance of 0·66 m from dance band drums; other instruments produced sound levels only slightly lower. These levels are well above those at which threshold shifts might start to occur.

2.3.3. Line-Scan Whistle

The line-scan whistles from 405-line television equipment are exceedingly disturbing to many people. It is important to know whether actual physical damage to the hearing is a possibility with those who work in technical areas in which high levels of line-scan whistle are present. Little is known about the physiological damage caused by sounds of such high frequency. No previous investigations have been carried out since this frequency region is of little interest to most hearing conservation authorities, who are normally concerned with speech intelligibility.

Measurements of line-scan whistle levels were made in several areas at Television Centre and the highest levels found are given in Table 3.

The standing wave ratios were measured and all were below 10 dB; as the pressure levels given above are at peaks of the standing wave system, regions of higher pressure are not anticipated. The peak pressure levels measured are well below those which, at lower frequencies, are quoted as constituting damage risk with long exposure.

In order to find the sound pressure level at a frequency of 10 kHz that will induce temporary threshold shift (t.t.s.), members of Acoustics Section of Research Department were exposed to 10 kHz tone for periods of 30 minutes in a large free-field room, and their thresholds of hearing were measured before and after exposure. The results showed that exposures to sound pressure levels of 90 dB at 10 kHz for periods of 30 minutes produce no measurable t.t.s. although the subjects complained of tinnitus and of hearing random noise at the end of the test. It was not considered necessary or prudent to increase the test levels above 90 dB to find the level for the onset of t.t.s.

It was concluded that the sound pressure levels due to line-scan whistles will not cause any damage to hearing, but may well give rise to feelings of discomfort. Discomfort to the ears is certainly felt by many individuals at levels below 60 dB and may become worse rather than more tolerable during a period of exposure.

Methods for the reduction of line-scan whistles are well-known and they are not costly. There is therefore no reason for accepting television equipment which is not properly silenced. Levels of only 40 dB have been measured at 1·3 m from a television camera not incorporating any specific devices for reducing whistle and the specifications suggested later in this report for television equipment are entirely practicable.

2.4. Subjective Determination of Acceptable Background Noise

2.4.1. Experiments Using Programmes with Added Noise

The audibility of background noise in a broadcast programme depends primarily upon the nature of the noise and the maximum and minimum intensities of the wanted sound. The intensity of the wanted sound depends in turn on the strength of the source and the distance of the microphone, while the nature of the noise might be specified in terms of the spectrum, the intensity and continuity, and whether it was meaningless noise (as ventilation noise) or having a recognisable information content such as speech or the noise of a motor horn.

TABLE 3

Line-Scan Whistle Levels in Television Centre V.T.R. Areas
(rel. 2×10^{-5} N/m^2 r.m.s.)

10 kHz (405 lines)	15 kHz (625 lines)	20 kHz (i.e., 2nd harmonic of 10 kHz)
68 dB	60 dB	63 dB

It seemed at first a reasonable assumption that the level of noise which would be acceptable on a programme could be predicted in terms of these variables, and accordingly Research Department subjected them some years ago to a thorough exploration. The results have not been reported since the investigation did not achieve its primary object of predicting unequivocal absolute background noise tolerances. Nevertheless, some useful conclusions arose from this study, and a brief account of the work will be given here.

The experiments were designed to discover firstly the least tolerable ratio of speech to background, the noise being confined to octave bands, secondly the manner in which the various bands were combined, and thirdly the effect of the type of programme and the information content of the noise.

Subjects were asked to classify noise superimposed on recorded extracts of speech or music into five categories ranging from "imperceptible" to "very disturbing". Tests were carried out by two experimenters with both engineering and non-engineering subjects, and two listening rooms were used. In one series, similar results were obtained by asking the subject to classify the recorded mixtures of programme and noise in a series of categories from "imperceptible" to "very disturbing" and by asking the subject to adjust the noise level until he considered the noise "just disturbing".

The conclusions from the series were:

(1) The audibility of the noise depends not only on the signal-to-noise ratio, but also on the absolute noise level. This explains the normal practice of increasing monitoring level in order to assess background noise.

(2) For a given peak programme level, the curve of the greatest tolerable signal-to-noise ratio follows the curve of ear sensitivity against frequency near the threshold of hearing.

(3) Absolute signal-to-noise ratios could not be assigned to particular studios or programmes because of the number of variables unsuitable for numerical expression.

2.4.2. Determination of Acceptable Background Noise by Experience

The implication of the third conclusion from the above-mentioned subjective experiments was that the only feasible method of fixing background noise tolerances was on a purely empirical basis, using the other conclusions as supporting evidence. Much the same procedure has been followed by Beranek[8] and by Kosten and Van Os[9] who have published a series of curves of sound pressure level of noise (in octave bands) against mid-band frequency from which the most appropriate can be selected for a particular situation.

Records have been kept for many years by Research Department of the spectrum of the total background noise for every studio in which acoustic measurements have been made. These have been compared with assessments of the noise as heard as a background to programmes. The principal source of noise is usually the ventilation system and the individual spectra therefore tend to be all of the same shape, and similar to those found by Beranek and by Kosten and Van Os.

For the purpose of specification, it has been found that studios may be divided into three groups having similar background noise requirement, as follows:

Group I Sound Studios for Light Entertainment
(Highest tolerance allowed)

Group II All Television Studios
All other Sound Studios except Drama

Group III Sound Drama Studios

Fig. 1 shows spectra of maximum tolerable background noise due to all sources in studios divided into their three types. They represent r.m.s. measurements in octave bands as specified by B.S. 2475 : 1964. The curves, which are recommended as a basis for specifications covering ventilation systems, cameras and other sources of noise, were obtained by examination of the records of sound and television studios and comparison with subjective merit; the octave-band readings thus obtained were then weighted by an arbitrary factor of 4 and averaged with the recommendations of Beranek[8] and of Kosten and Van Os[9], which did not depart very seriously from our own figures.

It is important to note that the curves of Fig. 1 are higher and in some instances considerably higher than those used by other broadcasting organisations. Fig. 2 shows specifications for background noise in studios published by Kosten and Van Os[9] for Dutch studios by Kuhl[10] for W.D.R. Studios and by the O.I.R.T.[11] and these specifications are being achieved on the Continent. Nevertheless the present work has shown that the curves of Fig. 1 should represent satisfactory conditions; they will be less costly to achieve than the lower curves recommended by the other authors. At the same time, it must be clearly understood that the noise

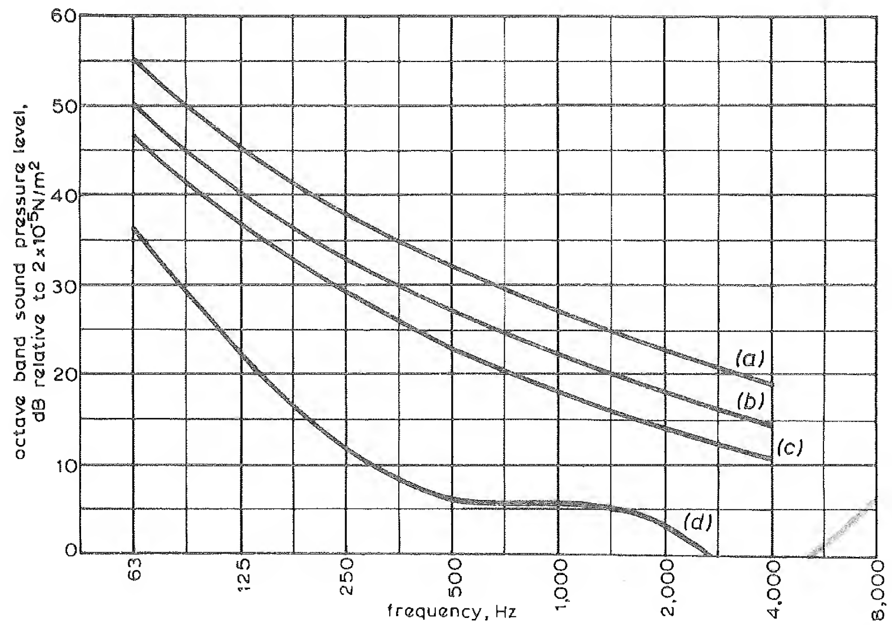

Fig. 1 - Permissible background noise levels in studios, from all sources

(*a*) Sound studios for Light Entertainment
(*b*) Sound studios (except Drama). All television studios
(*c*) Sound Drama Studios
(*d*) Threshold of hearing for continuous spectrum noise (Robinson and Whittle(14) 1964)

Note: Control cubicles, sound control rooms, etc. should conform to the curves appropriate to the studios with which they normally work.

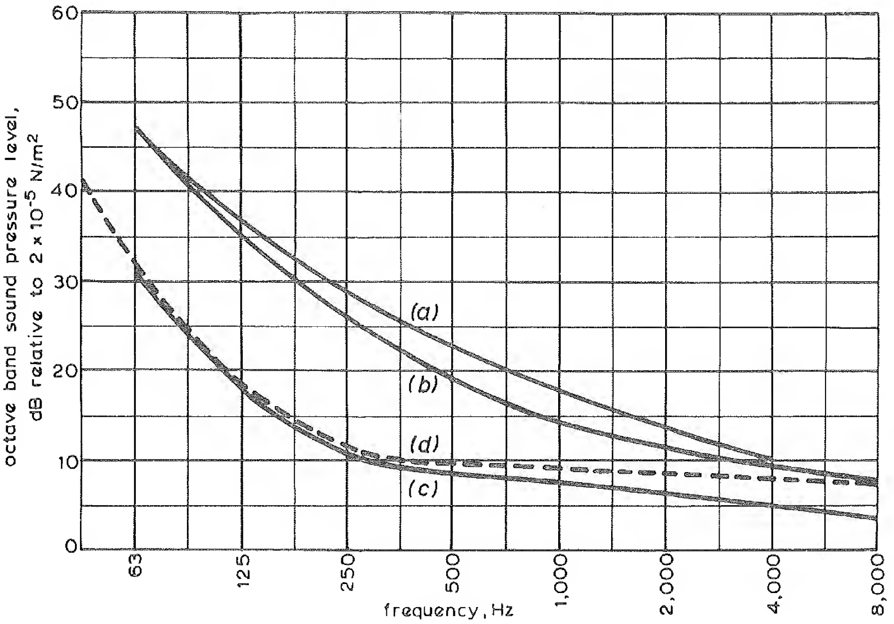

Fig. 2 - Permissible background noise levels in sound studios

(*a*) BBC Sound Drama
(*b*) Kosten and van Os
(*c*) Kuhl
(*d*) Oirt

levels represented in Fig. 1 are the maximum permissible if good programme quality is to be maintained. The silencing of television studios is, of necessity, an expensive undertaking and, in certain cases, it has not been possible to conform to the levels shown, with the result that to produce satisfactory drama transmissions, it is necessary to introduce bass-reducing filters in the sound chain. Some slight impairment of speech quality inevitably results and whenever possible the users switch off the ventilating plant during actual recordings of such programmes.

2.4.3. Study of Noise in Television Productions

Research Department obtained the co-operation of Television Operations and Maintenance Department in collecting comments from sound mixers during programme rehearsals. The sound mixers take the steps necessary to reduce audible background on programmes where it is due to ventilation systems, camera blowers, camera dollies or trailing cables, and these steps were detailed in reports of programme extending over several months. These comments established that all studios were too noisy at the time, both with respect to ventilation (which often had to be shut down during transmissions or recordings), camera blower noise and cable noises. They also indicated an order of merit of the four Television Centre sound control rooms then in operation which was the same as the arrangement of the rooms in order of measured noise level, and established that control rooms should comply with the same maximum noise curves as the studios with which they are used.

2.5. Specifications

2.5.1. General

All specifications in this section are expressed as octave band spectra as measured by an r.m.s. meter. In practice, two types of specification exist:

(1) Those specifying the maximum noise level consistent with completely acceptable programme quality, i.e., the noise levels below which reduction produces no significant improvement in broadcast quality.

(2) Those fixing a noise level which, while not being completely acceptable, is considered to be the lowest it would be practicable to demand. In such cases, a specification may be a temporary one, intended to enforce a reasonable standard until quieter designs of equipment, for instance, are available. These will be referred to as holding specifications.

The aim in specifying noise levels for equipment to be used in studios is to ensure that the total noise power at the microphone due to all sources will not exceed the values given in the appropriate curve of Fig. 1. For this reason, if it is expected that two sources of sound of similar spectral form are likely to be equally audible at the microphone, each should be made 3 dB below the total noise curve. These considerations apply only to the first type of specification.

2.5.2. Ventilation Noise

In a sound studio, ventilation noise is the only continuous background noise to be considered, assuming that traffic noise has been adequately excluded. The specification for ventilation noise should therefore follow the appropriate curve in Fig. 1.

In a television studio, however, apart from ventilation noise there is usually noise from camera cooling fans, cables trailing on the floor, spot lights, scenery hoists, etc., and it is necessary to consider these when specifying the maximum noise level of the systems. Of these sources of noise, only the camera cooling fans and fluorescent lighting are run continuously during the programme; the others will be intermittent and have characteristic timbres.

Therefore cameras, at the closest working distance to the microphone, and ventilation systems should conform to a curve 3 dB below the criterion curve for a television studio. However, the lowest noise curve which appears at present to be attainable at Television Centre from a ventilation system lies close to the criterion curve and the great majority of systems give levels 10 dB higher. For this reason it has been the practice to accept the criterion curve as a practical compromise; only in two studios is the noise level as low as this. Until experience is available with more studios of comparable noise level, no purpose is served by a rigid application of the specifications.

A specification is sometimes called for in the design of a ventilation system which is being installed at low cost on the understanding that it will not be used during actual transmissions or recordings, but only to renew the air before and after use. Such a specification is almost bound to be unsatisfactory. If the ventilation system is used for rehearsals, the artists and production staff will be upset by the contrast between rehearsal and transmission conditions. If the intention is to turn off the ventilation for rehearsals also, it is the universal experience that rehearsals will on many occasions last too long to be completed without a change of air, and the decision must be made whether to interrupt the rehearsal or tolerate excessive noise.

Further investigation of this question has been started, but the present view is that a specification to cover such cases is of no value.

2.5.3. Noise of Equipment

Equipment may be divided into two classes:

1. Equipment to be used in Television or Film Studios or their control rooms. This includes:

   Television Cameras: The noise from these includes that from cooling fans and line-scan whistles.

   Blowers for Control Room Equipment

   Scenery hoists intended for use during transmissions or recordings.

   Revolving Stages (Proposed for some studios).

   Eidophor Back-Projection Equipment

   Film Cameras

Three of these sources of noise are continuous and random - camera blower and line-scan, equipment blower and Eidophor noise.

Camera and equipment blower noise will be present in the studio and control rooms respectively during every programme. Ultimate specifications

should therefore be referred to the minimum working distance of about 1·3 m and call for a figure of 3 dB below the total noise specification for the area.

Eidophor noise is of a similar type but will only occasionally be present. It would be uneconomic to reduce ventilation and camera noise to allow for this as a third source, especially since the existing Eidopher installations are so noisy that only a holding specification may be possible.

The intermittent sounds, such as camera turrets, dollies and cables, scenery hoists and the proposed revolving stages still remain for consideration. As most of these are of recognisable timbre, each source should ideally be individually quietened until it is imperceptible against the general background. This implies that the permitted noise levels at microphone positions should be, say, 5 dB below the total noise curves, a condition which is unlikely to be attained.

The only practicable course is therefore to lay down individual holding specifications for each item of equipment to limit the noise to a reasonable figure and to organise the use of the equipment so that it is only used on transmission when the noise is masked by programme sounds. Equipment of this type will always be audible if used in quiet parts of the programme. The noise from camera dollies and the swishing of cables is so dependent on operation that no specification can be suggested.

2. Equipment Used in Mobile Control Rooms or Similar Vehicles

It is worthwhile establishing holding specifications for total noise in mobile control rooms or similar vehicles since they are normally equipped completely by a single contractor. These vehicles are intended for use in public places, and because of their light construction there is usually very little protection against external noise. Moreover, there is a great deal of equipment in a small volume and the ventilation system and equipment blowers are therefore necessarily obtrusive. A specification designed to give complete subjective satisfaction is therefore unnecessary and probably not practicable.

With these considerations in mind a holding specification was proposed to S.P.I.D. according to Fig. 3, based initially on measurements in existing M.C.R.'s and the shapes of the equal-loudness contours of the ear.

2.5.4. Line-Scan Whistle

The purely physiological effects of line-scan whistle have been dealt with in Section 2.3.3. To avoid annoyance also to those working in proximity to cameras and monitors it should be sufficient to reduce the level so that it lies on the same equal loudness contour as that which agrees most nearly at 2 and 4 KHz with the studio ventilation noise curve. This leads to levels of approximately 25 dB (relative to 2×10^{-5} N/m^2) at 10 kHz and 35 dB for the 15 kHz whistle, at which they would appear no louder than the higher frequency components of ventilation noise. A provisional specification of 40 dB at either frequency could be met without difficulty and would lead to a considerable improvement in the environment of television staff. Whistle

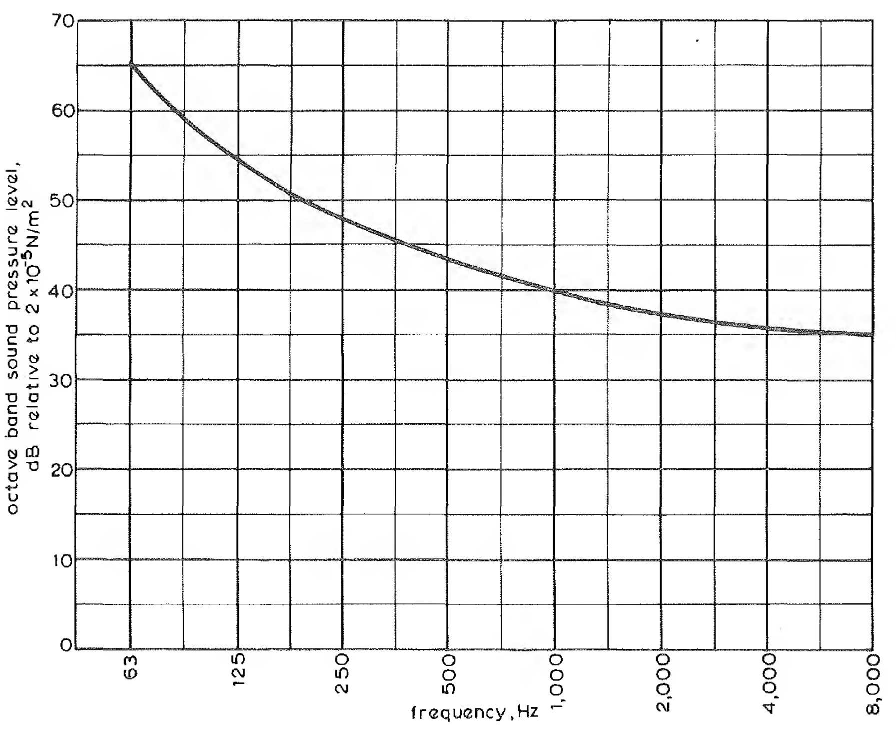

Fig. 3 - Permissible noise levels in the working areas of Mobile Control Rooms

(Separate specifications for ventilation and equipment noise must be 3 dB lower than the curve at all frequencies)

picked up at this level from cameras by studio microphones would not be audible on most domestic receivers.

2.5.5. Acceptance Measurements

The general methods of measurement have been described in Section 2.2.1. above. Carrying out these measurements on quiet equipment may present some difficulty, requiring a very quiet background and acoustically dead surroundings. For instance, a television camera blower must produce a sound at, say, 1·3 m distance, no more than that of the studio ventilation system as measured in a typical microphone position. To reduce the effects of reverberant sound and noise, a very close measuring position is necessary, and it has been agreed to use 1 m as the standard distance between the measuring microphone and the nearest point on the equipment. This is in line with the current I.S.O. standard on machine noise measurement. A large television studio is ideal for measurements since at a distance of 1 m the reverberant sound field is negligible compared with the direct radiation from the equipment.

In the absence of a large dead studio, the best way is to choose a room as large and acoustically damped as possible and compare the noise of the equipment with that of a falling ball calibrator (as sold by manufacturers of sound level meters) placed in the same position.

Another difficulty is the provision of a high enough signal-to-noise ratio in the measuring apparatus to make measurements possible on quiet equipment, especially in the high octave bands. The necessary apparatus should include a sensitive low-noise microphone, a low-noise amplifier giving about 120 dB gain and a zero-level indicator. Commercial sound level meters with filters are all inadequate for this purpose.

3. SOUND INSULATION

The first section of this report specified the maximum permissible background noise level for different types of broadcasting studios. It is not normally possible to locate studios in noise-free surroundings, and so precautions have to be taken to insulate the studio from external noise sources.

Adjacent studios may be used for programmes of widely different types, and it is therefore essential to insulate adjacent studios, control cubicles, recording rooms, etc. from each other. In certain localities such as studio centres close to surface or underground railway lines, high noise levels may be produced by radiation into the studio of structure-borne vibration of the walls. This section of the report discusses the measures which have to be taken to ensure that the sound insulation provided by the boundaries of the studio is adequate, and specifies sound insulations and structure-borne vibration criterion curves for the different types of studios and other technical areas.

3.1. Airborne Sound

3.1.1. External Airborne Noises

A preliminary survey of the proposed studio site will enable the sound pressure levels of external airborne noises to be measured. Some indication of typical S.P.L.'s in noisy environments

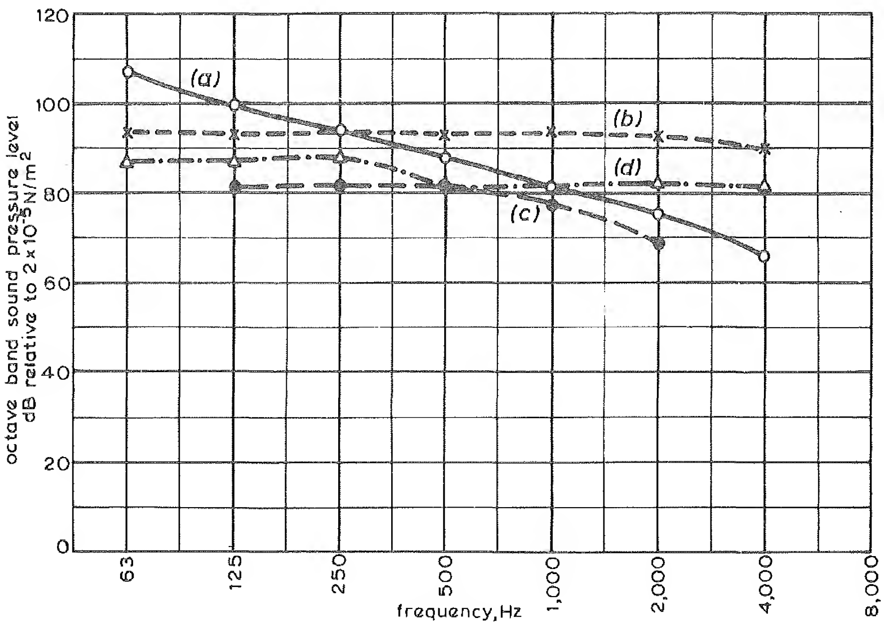

Fig. 4 - Octave-band analysis of aircraft noise, sonic booms and heavy road traffic noise
(*a*) Sonic booms (*b*) Aircraft
(*c*) Helicopter
(*d*) Road traffic in busy city street

is given in Fig. 4, which shows octave-band pressure levels for sonic booms, jet aircraft, helicopters and for traffic noise on a busy city road. The appropriate background noise criterion curves for different types of studio have been given in Fig. 1 of this report. Knowing the permissible background noise levels and having measured the airborne noise level at the site to be occupied by the studios, one can then calculate the required sound insulation for the studios.

Sound insulation is often quoted, for example by the B.S.I., as a single figure, in dB, representing the average of all the values read at one-third octave intervals in the frequency band 105 Hz to 3·2 kHz. In the BBC it has been customary to substitute the mean of the half-octave values from 125 Hz to 2·8 kHz. Either procedure gives a rough indication of the effectiveness of the insulation but it is not sufficiently precise for checking the behaviour of the boundary wall.

3.1.2. Sound Generated in Adjacent Areas

The insulation requirements between technical areas can be specified from a knowledge of the probable sound pressure levels associated with the programmes in them. It has already been seen that the range of permissible background noise in any frequency band in sound studios is included in a range of only 4 dB. Therefore, the insulation to be provided between two areas depends almost entirely on the maximum programme S.P.L.'s produced in the source studio. The programme levels in speech studios are lowest, followed by drama studios using "acoustic effects" and cubicles, recording rooms, etc., in which loudspeaker monitoring is carried out. Light music, symphony orchestra and "pop" music studios with electronic instruments generate the highest S.P.L.'s in the same order.

The requirements for insulation between talks studios and their related areas have been dealt with in an earlier report.[12] The least stringent requirement is between a talks studio and its cubicle, Fig. 5, curve (*a*). It should be sufficient to prevent the sound of the monitoring loudspeaker from affecting the speech quality from the studio and to prevent conversation in the cubicle from being heard over the microphone. At low frequencies a high enough insulation must be provided to prevent howl-round between the cubicle loudspeaker and the studio microphone at the highest listening level available from the loudspeaker.

From a cubicle to an adjacent cubicle and from a studio to an adjacent studio the insulation required is slightly higher, though howl-round is not a factor (Fig. 5, curves (*b*) and (*c*)).

Curve (*d*) shows the insulation required between a studio and a cubicle, recording room or tape editing room in which a loudspeaker may be radiating a different programme. It includes the case of a cubicle monitoring its own studio through the playback head of a recording machine.

Curve (*e*) represents the insulation required between a "pop" music studio and a talks studio. The mean value is 68 dB.

To obtain the sound insulation required between any of the above areas and a drama studio, 4 dB should be added at all frequencies.

3.2. Structure-Borne Noise

If the studio centre is located near to a railway line, or to a main road carrying heavy vehicles, the structure of the building will be forced into vibration. Vibration of the walls of an enclosure

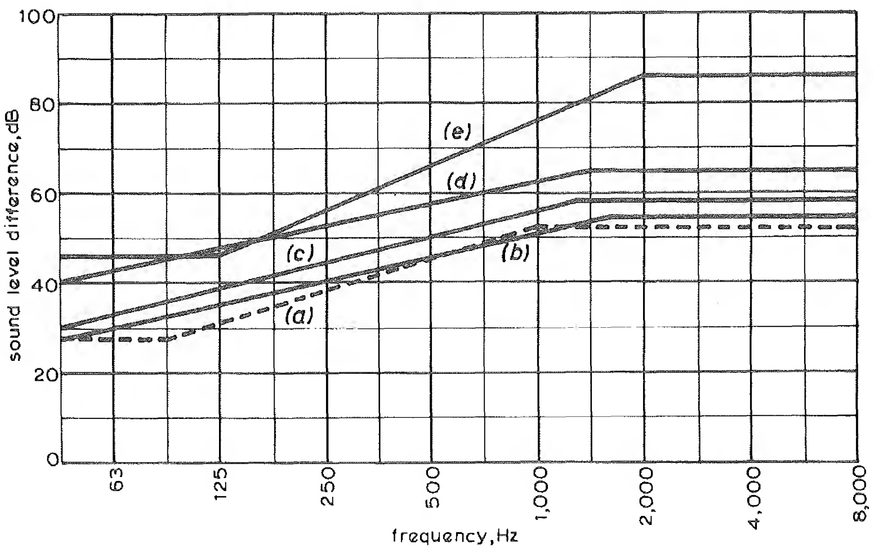

Fig. 5 - Sound insulation criterion curves

(*a*) Talks studio to its own cubicle
(*b*) Cubicle to adjacent cubicle
(*c*) Talks studio to talks studio
(*d*) Talks studio to its own recording room and to cubicles, editing channels etc. in which a loudspeaker radiates a programme different from the studio.
(*e*) Orchestral and popular music studios to talks studios.

will radiate sound into the enclosure and the sound level to be expected inside can be calculated from the vibration amplitude of the walls. Thus, referring to the permissible background noise levels for the studio given in Fig. 1, we can calculate the maximum permissible vibration amplitudes of the surfaces.

A survey of the proposed site should be made and the acceleration amplitudes produced by adjacent rail or road traffic measured. If it appears that these levels are too high, it will be necessary to mount individual studios on anti-vibration mountings. The most usual method is to build an inner room inside the studio shell, the walls and ceiling of the inner room being carried on a reinforced concrete raft, which is isolated from the building framework by rubber pads, cork pads or other compliant anti-vibration mountings. It may also be necessary to utilise this type of construction to isolate talks studios from adjacent orchestral and "pop" music studios in which very high sound pressures are produced, or to isolate studios from adjacent areas containing rotating or reciprocating machinery.

4. SPECIFIC RECOMMENDATIONS

4.1. Airborne Sound

Reference to Fig. 1 and Fig. 4 indicates that the roof of a studio must provide a minimum of 65 dB of mean sound insulation against aircraft noise.[13] This leaves no margin to accommodate any further increase in aircraft noise. A double-skin roof is required to achieve a 65 dB sound insulation and the additional cost required to increase the insulation to 70 dB will be a very small fraction of the total cost of a double-skin 65 dB roof. It would therefore appear false economy to design roofs with less than 70 dB sound insulation.

The studio walls are screened to some extent from aircraft noise and experience indicates that an insulation some 6 dB less than that of the roof (59 dB if no provision is to be made for a future increase in aircraft noise) will suffice for the walls. From Fig. 4 it can be seen that road traffic noise is more than 6 dB below aircraft noise and thus an insulation of 6 dB less than that of the roof will also be adequate for road traffic noise.

4.2. Structure-Borne Sound

It is unlikely that the whole of the studio wall areas will vibrate in such a way as to produce in-phase pressure components. The maximum permissible acceleration amplitudes of the wall surfaces may therefore be defined as those that will produce a near-field sound pressure which conforms to the appropriate criterion curve of Fig. 1.

Fig. 6 shows the maximum permissible acceleration amplitudes of the wall surfaces to ensure that the vibration shall not produce sound pressures (near field) in excess of the noise criterion curves.

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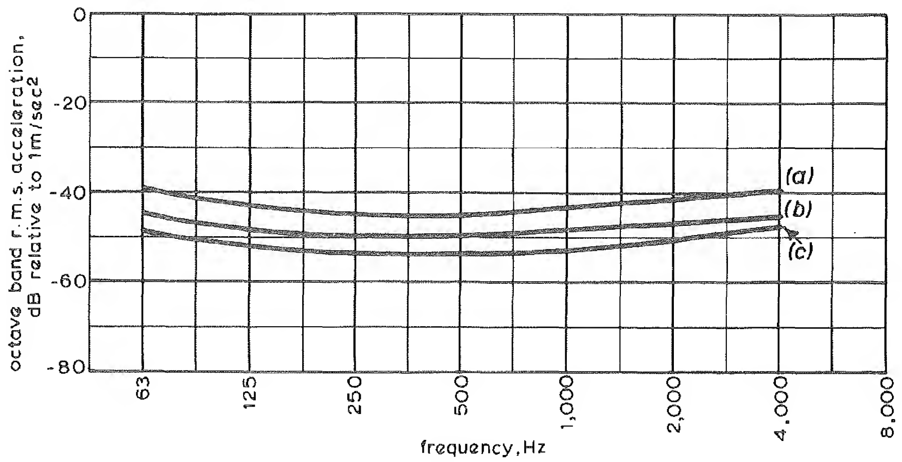

Fig. 6 - Permissible accelerations (r.m.s.) of boundary walls of studios. (Derived from noise criterion curves of Fig. 1)

(*a*) Sound studios for Light Entertainment
(*b*) Sound studios (except Drama). All television studios
(*c*) Sound Drama studios

Note: Control cubicles, etc. should conform to the curves appropriate to the studio with which they normally work.

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